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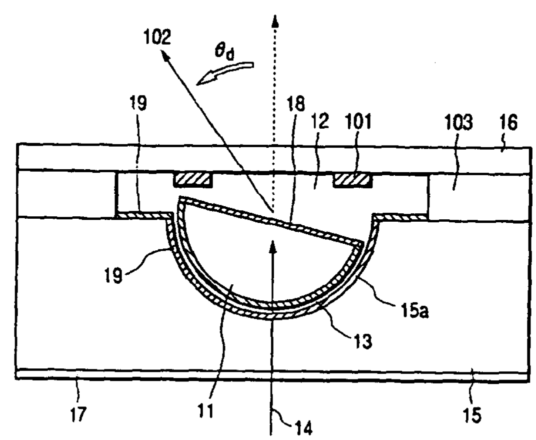
(54) Light deflection device and array thereof

(57) A light deflection device comprises a segmental sphere body (11) having a deflection face portion for deflecting and transmitting an incident light beam, and a segmental sphere face portion opposing to the deflecting face portion, a base plate (15) for supporting the segmental sphere body in a turnable manner, and a driving means (18,101) for turning the segmental sphere body, the refractive index of the segmental sphere body being different from the refractive index of a space (12) or medium brought into contact with the deflection face portion.

A light deflection device array comprises the light deflection devices arranged in a one-dimensional or two-dimensional array.

FIG. 1



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invention.

Fig. 6 is a schematic sectional view of a fourth example of the light deflection device of the present invention.

Fig. 7 and Fig. 8 are perspective views of an array of the light deflection device in a fifth example of the present invention.

Fig. 9 is a perspective view of an array of the light deflection device in a sixth example of the present invention.

Fig. 10A and Fig. 10B are schematic views for explaining the principle of deflection in the light deflection device of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0009] The present invention utilizes light refraction at interface 93 between two mediums having refractive indexes different from each other as shown in Fig. 10A and Fig. 10B. With interface 93 not tilted as shown in Fig. 10A, incident light beam 91 passes through without deflection.

[0010] In the present invention, as shown in Fig. 10B, the interface between the two mediums having different refractive indexes (n_1 and n_2 in the drawing) is tilted relative to incident light 91 in a three-dimensional space to control the direction of refraction of transmitted light beam 92. In practicing this principle, the controlling interface 93 only should be tilted without influence of other interface on the light transmitted through the entire device. A specific practicable means is shown in Fig. 1, which utilizes the difference between refractive indexes of controllably turnable hemisphere 11 and medium 12 in contact with the deflection face portion of the hemisphere. The interface for changing the tilting angle, opposite to the deflection face portion, is in a spherical shape, and the contact interface between receiving base plate 15 and hemisphere body 11 is designed so as not to cause the refraction to be generated by mechanism of controlling the turn movement. For this purpose, a measure is taken, for example, such that optical matching oil 13 having the same refractive index as the hemisphere body and base plate 15 is filled into the gap, or, if it is not practicable, the surfaces of hemisphere body 11 and receiving portion 15a are treated for antireflection and additionally a suitable matching oil is filled to the gap.

[0011] To decrease reflection loss of the light 14 to be deflected at the interfaces during the passage through the device and to prevent stray light, reflection prevention treatment is conducted not only at the aforementioned face for tilting angle change of hemisphere body 11 but also at supporting base plate 15 for supporting the segmental sphere body, the segmental sphere face of the segmental sphere body, turn-driving electrode 101, and support 16 thereof, or a window is opened therefor, as necessary.

[0012] Another specific embodiment below is also applicable. A base plate is comprised to support a segmental sphere body so as to be turnable freely around the center of a perfect sphere for the segmental sphere body, whereby the light beam deflection is controlled readily and precisely. The segmental sphere body may be supported as below. The base plate has a concave formed to support the segmental sphere body so as to be turnable. For supporting the segmental sphere body so as to be turnable smoothly and controllably, a lubricating material for reducing the reflection of the light to be deflected is filled into the gap between the segmental sphere body and the concave on the base plate. For the same purpose, the concave on the base plate is preferably in a shape corresponding to the shape of the segmental sphere body (in a shape of a segmental sphere like a hemisphere). Thereby, the force which is applied to the segmental sphere body in a direction toward the center of the segmental sphere body is caught by the concave to prevent displacement of the segmental sphere body to the force direction to ensure the turning movement of the segmental sphere body. The shape of the concave is not limited thereto, and may be in a shape of a cone, a cylinder, or the like.

[0013] The deflection face portion is typically in a shape of a flat plane. If necessary, the deflection face portion may be concave or convex. However, deflection control is easier with a flat face. The segmental sphere portion is typically in a shape of a hemisphere, so that the segmental sphere body comprised of the hemisphere portion can readily be supported in a turnable manner, and be relatively readily prepared.

[0014] The aforementioned driving means is constituted as follows.

[0015] In an embodiment, the driving means comprises an electrode provided on a segmental sphere body, and a separate driving electrode opposing thereto. The segmental sphere body is turned by electrostatic force generated by voltage application between the electrode on the segmental sphere body and the separate driving electrode.

[0016] In another embodiment, the driving means comprises a charge distribution formed on the surface of a segmental sphere portion of a segmental sphere body, and a driving electrode for generating an electric field around the segmental sphere portion. In this embodiment, the gap between the base plate and the segmental sphere body is filled with a dielectric liquid, and the regions of different charging characteristics are charged with a different polarity of electric charge. The segmental sphere body is turned by electrostatic force generated between the regions and the electrode provided on the base plate side. This constitution is simpler since the segmental sphere body need not be connected to electric wiring. Furthermore, since the electrode is provided on the base plate side, the electrode will not come into contact with the segmental sphere body, and the segmental sphere body can be turned

$$\theta_d = \theta_1 - \theta_2 \quad (1)$$

$$\theta_1 = \sin^{-1}[(n_2 \sin\theta_2)/n_1] \quad (2)$$

For example, with Si having a refraction index of 3.7 (n_2) at wavelength of 1.3 µm, and air having refraction index n_1 of approximately 1, hemisphere body 11 tilted by 10° deflects the outgoing light beam by a deflection angle θ_d of approximately 30°. In this Example, the light beam is introduced from base plate 15. However, the direction may be reversed to introduce the light beam from quartz base plate 16 in a plane parallel plate shape.

Example 2

[0024] Fig. 4 is a sectional side view of the device of a second example of the present invention. The bottom face of quartz base plate 41 having hemispherical concave 41a is coated with antireflection film 42 comprised of a multi-layer of MgF_2 and SiO_2. Hemisphere body 43 of quartz having nearly the same radius as concave 41a is fitted into concave 41a. Quartz base plate 41 having hemispherical concave 41a is obtained by isotropic etching of quartz base plate 41 through a circular hole of a Cr-Au mask with an aqueous hydrofluoric acid solution. The flat portion of hemisphere body 43 is coated with transparent electrode 44 comprised of an ITO film. The gap between hemisphere body 43 and concave 41a of base plate 41 is filled with optical matching oil 45 having the same refractive index as quartz. Therefore, no antireflection film is provided on the spherical surface of hemisphere body 43 and the surface of hemispherical concave 41a.

[0025] Quartz base plate 46 is placed above hemisphere body 43 with interposition of spacer 50. On the lower face of quartz base plate 46 above hemisphere body 43, four-divisional electrodes 47 are provided to exert electrostatic force to transparent electrode 44 formed on hemisphere body 43. Transparent electrode 44 on the flat face of the hemisphere body is brought into contact with electrode brush 49 extended from electrode 48 formed on base plate 41 to fix the potential of transparent electrode 44. Quartz base plate 46 at the light emitting side may be coated with antireflection film at the region surrounded by electrodes 47, or may be bored at that region of quartz base plate 46 to form a transmission window as shown in the drawing.

[0026] Example 2 is different from Example 1 in the method of fixation of the potential of the transparent electrode of the hemisphere body. However, the tilt of hemisphere body 43 is controlled as desired by voltage application to the four confronting electrodes in the same manner as in Example 1.

Example 3

[0027] Fig. 5 shows a third example of the present invention. The bottom face of quartz base plate 51 having hemispherical concave 51a is coated with antireflection film 52 comprised of a multi-layer of MgF_2 and SiO_2. Concave 51a is filled with transparent dielectric liquid 53, and therein quartz hemisphere body is fitted. The flat face portion of hemisphere body 54 is also coated with antireflection film 55.

[0028] Hemisphere body 54 is prepared from a microbead of quartz of 100 µm diameter by cutting a portion thereof by polishing to form a flat face. Then the flat face of this hemisphere body 54 is fixed on an adhesive tape. Onto the spherical face of the hemisphere body, MgF_2 is vacuum-deposited by sputtering to form a chargeable region 56a (for positive charging). A photoresist is applied on the surface of the hemisphere body. A portion of the photoresist is developed by light exposure, and the MgF_2 at the portion is removed by ion etching to bare the quartz glass partially to form chargeable region 56b (for negative charging). Thus regions 56a, 56b of different charging characteristics are formed on the spherical surface. In the case where the chargeable film is formed on the portion of the hemisphere body 54 corresponding to the path of the light beam to be deflected, the film should naturally be formed from a material transparent to the light beam 14 to be deflected. Above hemisphere body 54, transparent cover 59 coated with antireflection films 52 is placed with interposition of spacer 60.

[0029] The particle (hemisphere body 54 in this Example) in the dielectric liquid exchanges electric charges with the liquid to form an electric double layer to be charged positively or negatively. In this Example, formed chargeable regions 56a and 56b having different charging characteristics cause uneven distribution of the positive and negative charges between the regions, whereby hemisphere body 54 has an electric moment. Therefore, application of a potential to electrodes 57a, 57b exerts a torque to hemisphere body 54 to turn the pole direction in accordance with the direction of the electric field produced by electrodes 57a, 57b.

[0030] For example, on application of a positive voltage to driving electrode 57a and a negative voltage to the other electrode, charged region 56b turns to equilibrate its electric pole direction to driving electrode 57a. On application of a positive voltage to driving electrode 57b and a negative voltage to the other electrode, charged region 56b moves to equilibrate the charge pole direction to driving electrode 57b. The torque is offset when hemisphere body 54 has turned to equilibrate the vector of the electrical moment of hemisphere body 54 to the electric field direction. After the turn has completed, hemisphere body 54 is kept at that position unchanged owing to a frictional force of concave 51a without application of voltage. Further, when the electric field is applied again in a different direction, a torque is produced to equilibrate the electrical moment to the electric field to turn hemisphere body 54. In this Example, the potential of hemisphere body 54 need not be fixed from the outside. Therefore this embodiment is

[0041] A light deflection device array coomprises the light deflection devices arranged in a one-dimensional or two-dimensional array.

Claims

1. A light deflection device comprising a segmental sphere body having a deflection face portion for deflecting and transmitting an incident light beam, and a segmental sphere face portion opposing to the deflecting face portion; a base plate for supporting the segmental sphere body in a turnable manner; and a driving means for turning the segmental sphere body, the refractive index of the segmental sphere body being different from the refractive index of a space or medium brought into contact with the deflection face portion.

2. The light deflection device according to claim 1, wherein the base plate has a concave having internal face in a shape of a segment of a sphere, and the segmental sphere body is placed inside the concave.

3. The light deflection device according to claim 2, wherein a gap is provided between the segmental sphere portion of the segmental sphere body and the concave of the base plate, and the gap is filled with a medium for reducing reflection of the light beam.

4. The light deflection device according to claim 3, wherein the medium is a lubricating agent.

5. The light deflection device according to claim 3, wherein an antireflection film for preventing reflection of the light beam is formed on the concave of the base plate and the segmental sphere face portion of the segmental sphere body respectively.

6. The light deflection device according to claim 1, wherein the segmental sphere face portion of the segmental sphere body is a hemispherical face, and the deflection face portion is a flat plane.

7. The light deflection device according to claim 1, wherein an antireflection film for preventing reflection of the light beam is formed on the reflection face portion.

8. The light deflection device according to claim 1, wherein the base plate supports the segmental sphere body such that the segmental sphere is turnable within respective planes passing the spherical center of the segmental sphere body and perpendicular to each other.

9. The light deflection device according to claim 1, wherein the driving means drives the segmental sphere body by an electrostatic force produced between a first electrode provided on the segmental sphere body and a second electrode provided at a position in opposition to the first electrode.

10. The light deflection device according to claim 1, wherein the driving means drives the segmental sphere body by an electrostatic force produced by charge distribution caused on the surface of the segmental sphere body.

11. The light deflection device according to claim 1, wherein the segmental sphere body has a magnetic body as a part, and the driving means drives the segmental sphere body by a magnetic force produced by the magnetic body.

12. A light deflection device array, comprising the light deflection devices of any of claims 1 to 11 arranged in a one-dimensional or two-dimensional array.

FIG. 3

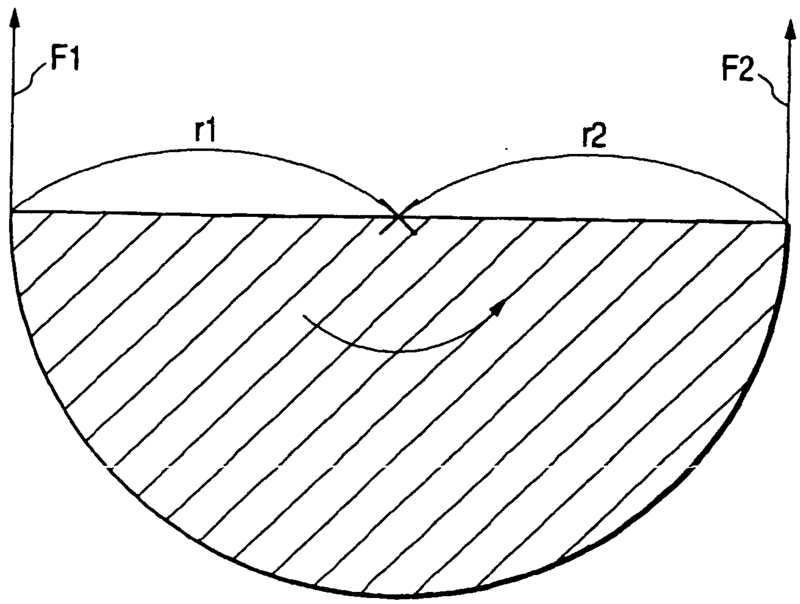


FIG. 4

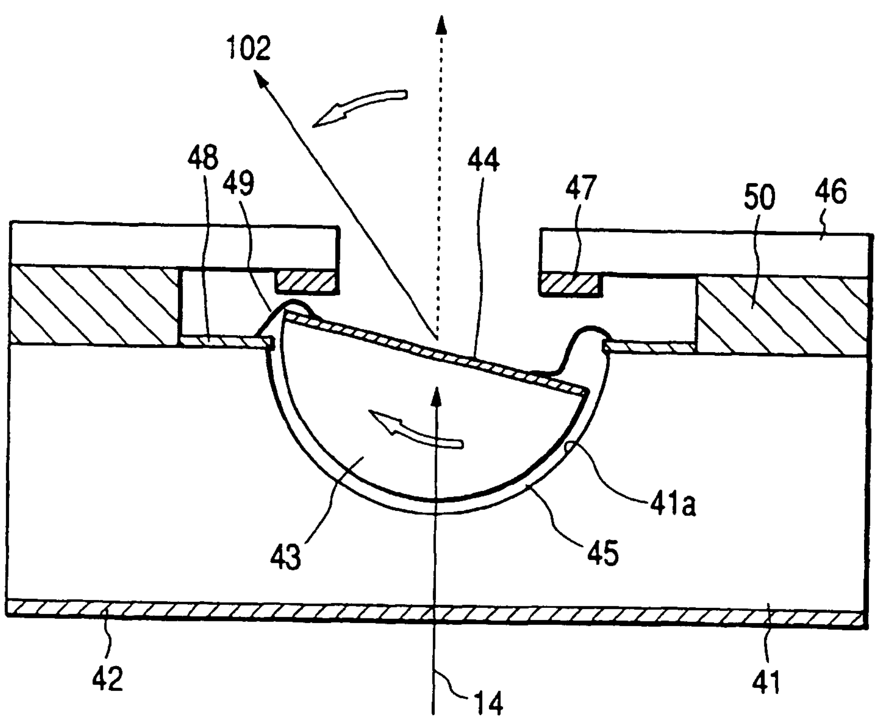


FIG. 7

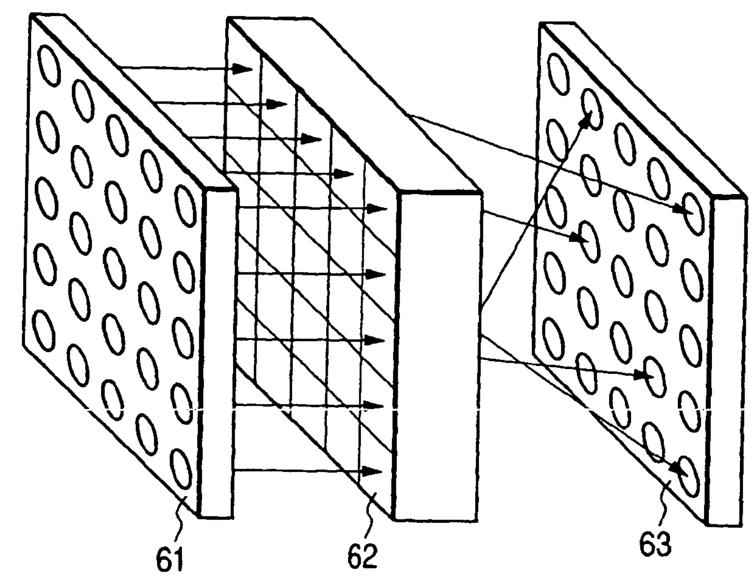


FIG. 8

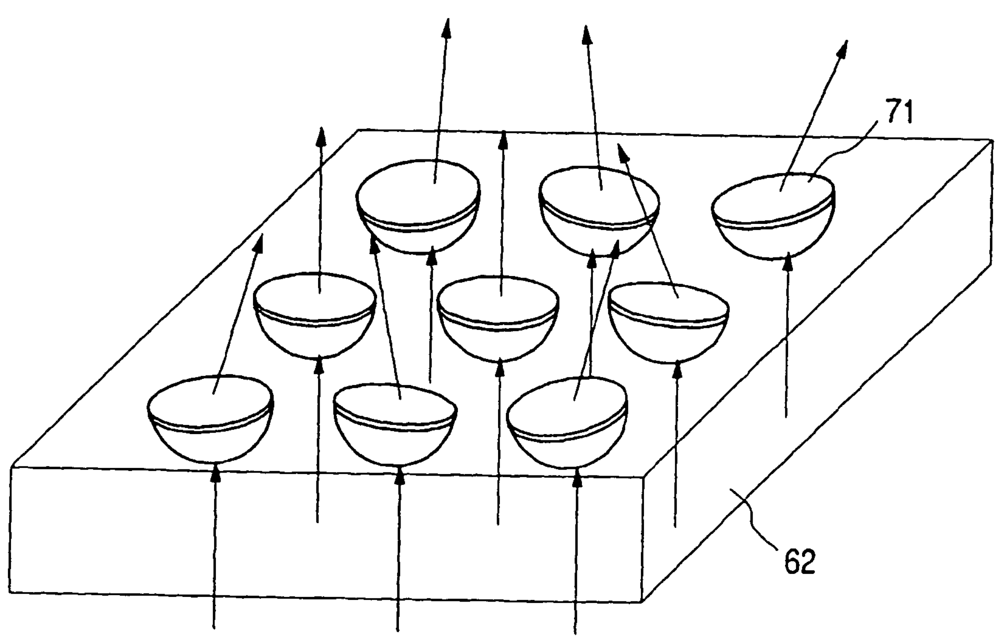


FIG. 10A

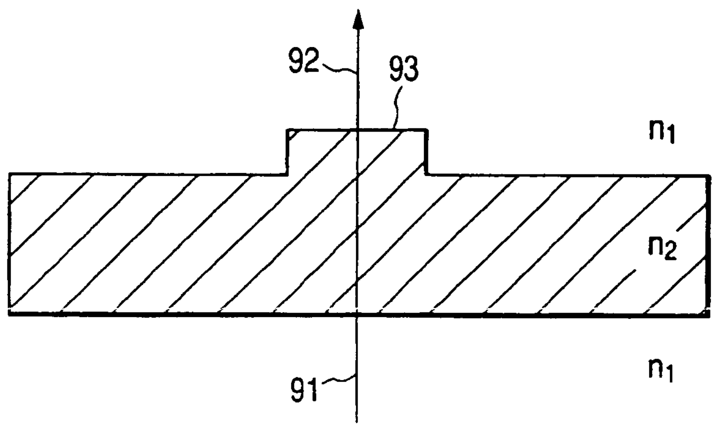
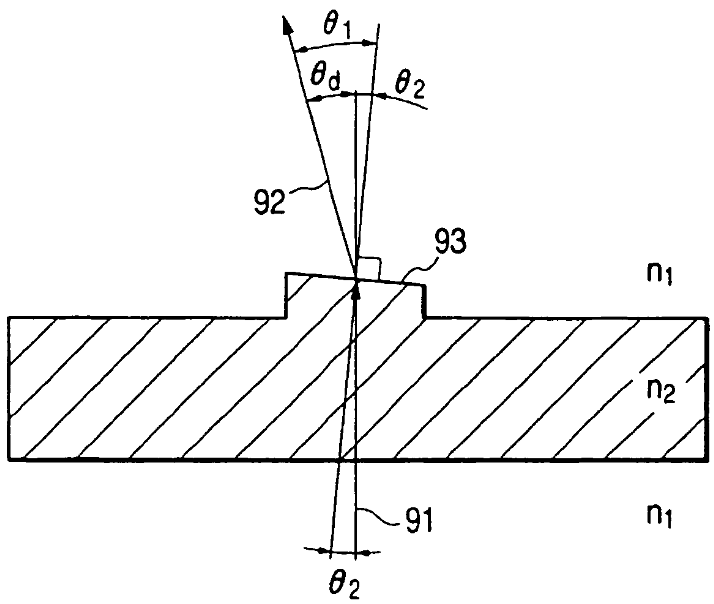


FIG. 10B



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